theme: nature

job: Chris Fawkes, BBC Weather forecaster (meteorologist)

activity outline

Using the context of a weather forecaster being able to predict wind speed and direction, pupils use knowledge of isobars to work out the wind direction on a weather map. They then investigate how a barometer works, pressure, force and surface area. They conduct a series of experiments using U-tubes, syringe pistons and force meters.

You will need one or two lessons, including an optional teacher demonstration.

The activities for How does a barometer work should be achievable by all pupils in one lesson.

The activity to investigate pressure, force and area is more involved – it may be better suited to more able pupils (with help from the teacher) in a separate lesson.

It is suggested that pupils work in small groups (2-3).

The pupil sheet provides an introduction (which provides information about how to work out wind direction on a weather map), a weather map and step-by-step instructions for each of these procedures, as well as a results table to complete.

Teacher notes overview

1 **Curriculum links:** where this activity can fit with the 2008 KS3 Programme of Study and Scottish 5-14 Science Curriculum.

2 **The Video:** providing a synopsis of the video content and ideas for viewing.

3 **The Practical:** including Equipment lists, Health and safety notes, a Possible approach (a comprehensive, suggested way of planning the lessons) and an Underlying science section (providing detailed information about the various scientific principles involved).

4 **Possible extensions:** suggestions for other practical activities using the video, or extending the suggested activity.

5 **Associated jobs:** guidance on how to deliver a plenary activity (or, if you wish, a stand-alone activity) focusing on the video interviewee, including a photo of the interviewee to place at the centre of a spider diagram.
### Curriculum Links

**This lesson can be used to help teach part of the 2008 Key Stage 3 Programme of Study (England and Wales):**

<table>
<thead>
<tr>
<th>Range and Content:</th>
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<td>3.1b</td>
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**Attainment Targets:**

- AT1, AT4

**Key Concepts:**

- 1.1a, 1.1b, 1.3*

**Key Processes:**

- 2.1a, 2.1c, 2.2a, 2.3a

**Curriculum Opportunities:**

- 4a, c, h

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**This lesson can be used to help teach part of the Scottish 5-14 Science Curriculum:**

**Main curricular links**

- E&F3 Forces and their effects

**Attainment Targets**

**Knowledge & understanding:**

- **Level E**
  - Describe the relationship between force, pressure and area

**Investigating skills:**

- **Level D**
  - Make an appropriate series of accurate measurements
  - Draw conclusions consistent with findings

* if Torricelli is discussed
the video

Synopsis of the video

Among other things, Chris makes these interesting points:

- The MetOffice uses a super computer to try to model the atmosphere; even though it’s one of the most powerful computers in the world, it still has to simplify the atmosphere because it’s extremely complex.

- Weather forecasters are still needed because they can look at the computer’s model, and compare this with human readings from around the country, thus spotting computer errors and tweaking the model.

- Weather presenters stand in front of a blank blue screen – they can’t see the maps that we see when we watch on the television.

- You need an excellent knowledge of physics to become a meteorologist.

 Watching the video

There are a number of things you might do before showing the video to your class.

1 Preview the video and write a few quick-fire questions. Then you can tell your class that they will be tested on their observation when it’s finished. This is an excellent way of encouraging them to pay attention!

2 Ask pupils to watch the video through once. Then ask them to generate one question that could be answered from the video and one question they would like to ask but the video did not answer. These questions are then exchanged with another pupil and the video is watched a second time. This gives pupils an opportunity to focus on something they may have missed first time, and provides a basis for discussion on what was learnt from the video, and what additional information is needed.

3 Ask pupils what sort of person might become a weather forecaster. Does anyone in the class think they’d like to work in meteorology? When the video has been watched, ask the questions again. Has anyone changed their mind/opinions?

4 Ask pupils to spot the science in the clip.
the practical

Equipment

(per group of 2 or 3 pupils)

- U tube (or manometer)
- small syringe attached to bung to fit U tube (attachment must be airtight)
- small trough (or large beaker)
- test tube
- plastic tube about 1m long
- clip to seal end of tube
- plastic tube 3 to 4m long (optional)
- access to dye solution to colour the water
- 3 syringes of different sizes, larger than the small one above
- short flexible tubing to connect syringes
- access to 50% detergent solution or similar, to lubricate syringe pistons
- 3 clamps + 2 stands
- 2 compression forcemeters
- step ladder or access to a staircase, if using the longer tube

Note: Try this experiment in advance to match forcemeter range to syringes used. The force required depends on how easily the pistons slide. The pistons in new syringes are already lubricated; used ones may need lubricating to minimise friction.

For water barometer demonstration (extension activity)

- plastic tube at least 10.5m long + sealing clip
- 10m of strong string or cord
- 15m tape measure
Possible approach

Ideally, the lesson should take place in a lab with a mercury barometer on the wall. (Warning: Do not attempt to remove the barometer or carry it elsewhere, since this could easily break the tube, resulting in mercury spillage.)

Introduce the concept of air pressure and its importance in plotting weather maps. [Note: at the top of the student sheet there is a weather map; students are asked, ‘What is the wind direction across Ireland?’ The answer is North West.] Discuss how the pressure is measured. Explain that the experiments show how a barometer works.

Pupils carry out the first set of experiments to show how air pressure can support a column of water. It is suggested that they work in groups of two or three. Discuss the results, emphasising the importance of forces in balance. Ensure that pupils understand the terms ‘force’, ‘weight’ and ‘pressure’ and their relationships.

If possible, with pupils’ help, demonstrate the water barometer extension activity, to show that air pressure can support a column of water some 10.3m high.

Theoretically, they could suck up a drink through a 10 metre straw, but not much higher. Ask why not. Lead discussion into explanation that suction is an illusion. The drink is being pushed up by air pressure, not being sucked up.

Introduce the mercury barometer, and its diagram. Point out the analogy with their water-in-a-trough experiment. Ask why it is less than 1 m high, rather than over 10m. Given that the density of mercury is 13.6 times greater than that of water, get them to calculate the height of mercury that exerts the same pressure as 10.3m of water. (Ans: $10.3 \div 13.6 = 0.757m$; i.e. about 75.7cm)

Explain what we mean by ‘pressure is force per unit area’ – including units.

**Note:** The SI unit is the Pascal (1 Pa = 1 N m$^{-2}$), but they will use N cm$^{-2}$ for convenience in their experiment.

Knowing that pressure is force per unit area, pupils now investigate whether the area of mercury exposed to air pressure affects the reading. If so how? If not why not?

They use a compression forcemeter to apply a known force to a syringe piston of known area. Hence they can calculate the applied pressure. This pressure exerts a force on the second syringe piston of different area. The resulting force is measured with a second forcemeter.

It is important that the pistons slide easily in the syringe barrels to minimise friction losses. Lubrication with 50% detergent solution may be needed.

Pupils try at least two, preferably three, syringes with pistons of different surface areas, taking readings for three applied forces for each syringe. Allowing for experimental uncertainty and inaccuracies, their results should indicate that statements 1, 4 and 5 in their worksheet are correct.

Discuss these conclusions and the reasons why they are true.

- Lead the discussions into explaining why the size of reservoir and width of the mercury column in a barometer do not affect the pressure readings.
Readings of atmospheric pressure are fundamental to weather forecasting. By plotting large numbers of readings, a pressure map is built up showing regions of high and low pressure. Isobars on weather maps are analogous to contours on physical maps – they join places with the same atmospheric pressure.

Like any other fluid, air flows from where there is a lot (high pressure) to where there is less (low pressure). High pressure forces air outwards towards the surrounding low pressure. “Winds always blow from high to low” is an easy rhyme for pupils to remember.

The Earth’s rotation causes the air/wind to be deflected to the right in the Northern hemisphere (and to the left in the Southern). Going into detail of the Coriolis force is probably not advisable at this level! (although Chris does mention it in the video).

The weight of the atmosphere (that is the force of gravity pulling the gas down) pushes on all surfaces. Air pressure is the force pushing on each square metre (or square centimetre) of surface. Normally we don’t notice this pressure because it is equally spread – as in the first U tube experiment.

Increasing the pressure on one side of the U tube causes an imbalance, which forces the water down on that side and up the other, until the pressure caused by the weight of the extra water balances out the extra air pressure.

If there is no air pressure on one side, the air pressure, without any extra, is sufficient to support a column of water. (Experiment part 2)

[Air pressure will support a water column over 10 metres high – but don’t mention this yet if the water barometer extension activity is to be performed.]

A mercury barometer is like the water-in-a-trough experiment – a tube of mercury standing in a reservoir, which is enclosed to avoid escape of poisonous mercury vapour. A small hole allows the changing atmospheric pressure to contact the mercury surface.

In some types (e.g. Fortin barometer) the mercury is held in a small leather bag.

Since mercury is much denser than water, a column of mercury is much heavier, so exerts a much higher pressure. Air pressure can only support about a 76cm column.
possible extensions

1 **Water barometer**
   This requires access to a window, or a stairwell, at least 10.5 m above ground level, and a plastic tube at least 10.5 m long.

   Completely fill the tube with coloured water, e.g. by gradually lowering the coils into a bucket. Holding the end under water, fold it over and clamp firmly to seal the end, ensuring that no air is trapped.

   Send one or two pupils up to the window with the cord and tape measure. Lower down the string or cord, and attach it to the sealed end of the tube. Carefully pull the tube upwards to window height, being careful to keep the lower end under water.

   Observe the column of water. Lower the zero end of the tape measure. Hold zero at the bucket water level, and read off the height of the water column. Depending on atmospheric pressure, it should be between 10 and 10.5 m high.

   Ask what is above the water level at the top of the tube, and where it came from. (A vacuum – caused by water dropping to the maximum height that the air pressure can support.)

2 **Pressure calculations**
   Weather maps normally show pressure in millibars (mbar). Relate these to barometer readings in mm Hg and SI units (Pa = N m\(^{-2}\)). Pupils use conversion factors to translate between units – but make these purposeful e.g. a barometer reads X mm Hg. How would this be plotted on a weather map in mbar? (Or vice versa.)

3 **Air pressure and altitude**
   Air pressure decreases with height. Discuss why and how this affects barometer readings. Given time, this could extend into mountaineering and passenger aircraft.

   **Note:** Readings collected for weather maps must be adjusted to their corresponding values at sea level before plotting.

4 **Historical development**
   For PoS 1.3 (Cultural understanding) pupils could research the invention and development of the barometer by Torricelli et al.
Aneroid barometers

Most dial-type wall barometers, with which pupils may be familiar, are aneroid. Show an example, or illustrations.

This type contains a sealed, flexible container, which expands and collapses slightly as the air pressure on it alters. This movement causes the pointer to rotate.

**Fig 1**
A STEM (Science, Technology, Engineering and Maths) education provides pupils with skills and knowledge that are useful in all sorts of careers. The video demonstrates how Chris, a BBC weather forecaster, uses such skills on a daily basis.

Chris works with numerous people – some directly, some indirectly. Some use STEM skills, others don’t. By exploring this network of associated jobs, pupils will, hopefully, begin to see that even those in non-STEM jobs will find STEM skills useful – if they’re communicating with someone “in-STEM”, for example, some knowledge of their work will be a great help.

Chris’s spider diagram

Try placing Chris at the centre of a spider diagram (we’ve provided a photo of Chris which you could use – see overleaf). You could either create worksheets for pupils to complete themselves, or create the diagram on your whiteboard and then pool ideas.

Ask pupils: “who does Chris work with”. They may draw information from the video – he talks about weather observers, for example – or they may come up with new ideas, such as the people who programme and maintain the super computer, or weather forecasters for other organisations, such as the military or airports. Other, less obvious, suggestions might include the people who design/make/maintain the various measuring tools – such as satellites, weather balloons, thermometers, barometers, anemometers, etc.

Now ask pupils which of those jobs are clearly “in-STEM”. Who else might find some STEM skills helpful? Why?

You could extend this by taking any one of the associated jobs and placing them at the centre of a spider diagram, and starting the process again.
Chris Fawkes, BBC Weather forecaster (meteorologist)

Studying science and maths can transform your career options. Future Morph: become someone.